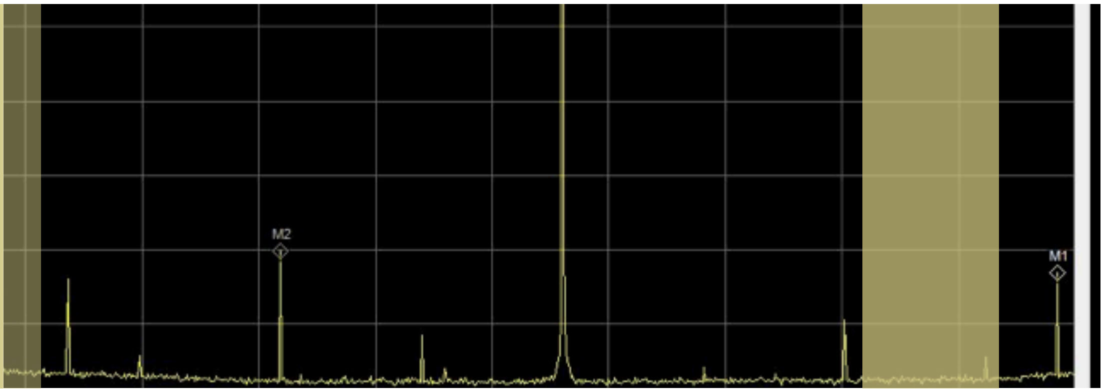

Tektronix RSA5100B Wide Band Acquisition Bandwidth Options

Technical Brief

Tektronix®

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Acquisition Bandwidth	Option B16x 165 MHz Acquisition Bandwidth	B16xHD, 165 MHz High Dynamic Range Acquisition Bandwidth
>40MHz <80MHz	-76 dBc	-80 dBc
>80MHz <165MHz	- 73 dBc	-80 dBc

Figure 1. Comparison of spurious free dynamic range options.

Introduction: Tektronix RSA51xxB wide band acquisition bandwidth options

Tektronix offers a choice of dynamic range in the high acquisition bandwidth options for the RSA5100B series real time signal analyzers. There are advantages and disadvantages for each solution, and this white paper examines the difference between these options, and how to choose between them. There are options from 85 MHz to 165 MHz bandwidth, and this paper focuses on results from the 165 MHz options to present the most difficult case. A video of the performance differences between the two options is available at www.tek.com/dynamicrange.

Both options provide up to 165MHz of real time analysis bandwidth over the frequency range of the RSA model. The differences are in the SFDR (Spurious Free Dynamic Range) with signal, other than CF (Center Frequency). All comparisons in this paper are of the published typical performance. See the data sheet for details; they are simplified here to cover all frequency ranges of the instruments. For spans less than 80MHz and for instruments up to 6.2GHz there is some improvement in these specs.

The B16x option is competitive with other manufactures providing up to 165MHz of real time bandwidth. This option has great performance for analysis of 802.11ac Wi Fi signals and for wideband real time spectrum analysis with DPX spectral displays and triggering. If the option B16x specifications meet your objectives then this option will work well for you.

If you desire a bit more SFDR and a cleaner spectrum, you may want to consider the B16xHD option.

The B16xHD option provides a cleaner and lower SFDR than the B16x option. By cleaner, we mean that the option B16xHD option has fewer distortion products of any type, and overall lower SFDR allows the user to look deeper and see signals without the instrument specifications limiting the measurement. Better SFDR also provides more headroom when measuring small signals in the presence of large signals without the need to consider distortion products created in the measurement tool.

In this paper, HD2 and HD3 refer to HD – Harmonic Distortion, 2 – second harmonic and 3 – third harmonic. These are generated in the intermediate frequency (IF) stage and the analog to digital converter (ADC). When harmonic distortions are generated in the IF/ADC, their location in the acquisition band can be difficult to predict. At any particular operating frequency, the location of the signal will depend upon the Nyquist zone selected for operation, whether high-side or low-side mixing products are used and the sampling rate. Changing the input frequency can cause the signals to move in opposite directions, at different rates. The example shown in this paper is repeatable, but you will get different interactions at other input frequencies. This IF distortion should not be confused with the instrument specification for front-end second and third harmonics. RF-input harmonic distortion is predictable based on the input frequency. For example, if the input is 1GHz, HD2 of the front end is 2GHz and HD3 is at 3GHz.

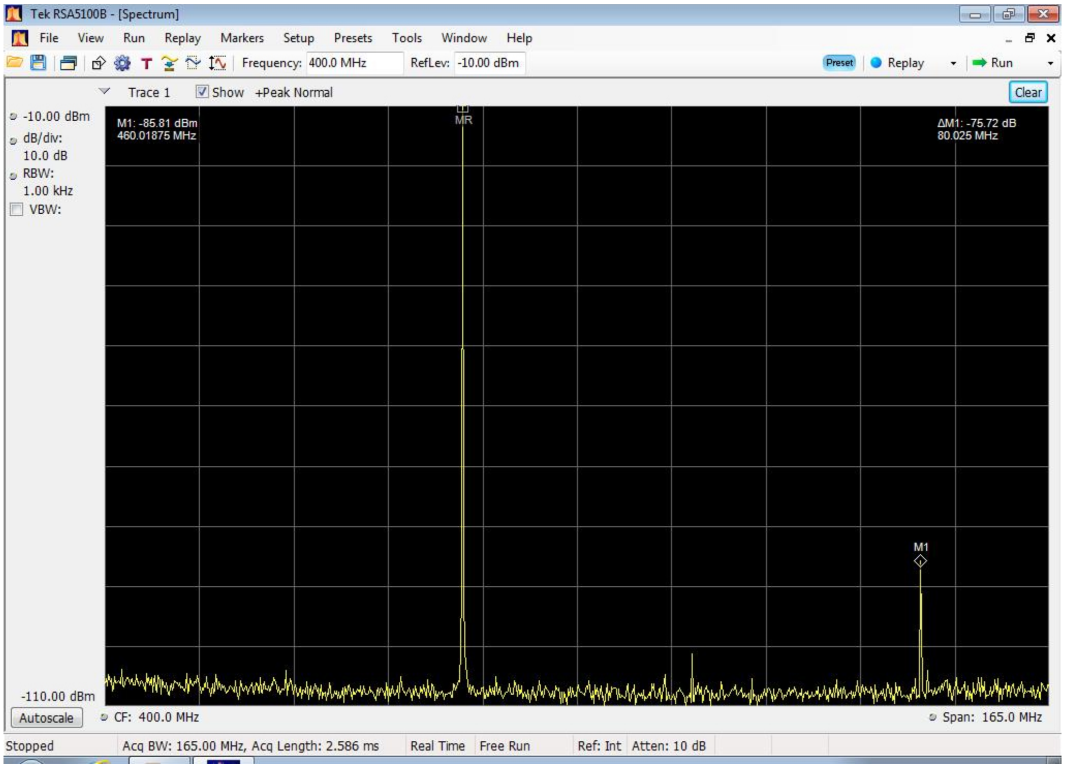

Figure 2. Performance of Option B16x showing IF/ADC-generated harmonic distortion at -75.72 dBc. The signal at M1 is the combination of HD2 and HD3 combine.

B16x Option

Figure 2 shows a signal at the reference level of -10dBm and the spectrum that you would typically see for a center frequency (CF) of 400MHz with a 380MHz tone applied to the input. The span is 165MHz. There are usually two or three signals created by the instrument that limit SFDR. The main component shown above by marker M1 at -75.72 dBc is the point where the HD2 and HD3 of the input signal in the IF are on top of each other. Remember, these HD2 and HD3 terms are generated only in the IF and are not part of the RF harmonic distortion specification. The above illustration has no averaging so the signal at M1 moves around many dB with noise. This screen shot has captured a high peak since HD2 and HD3 "beat" together and cause fluctuations in the level of the spur.

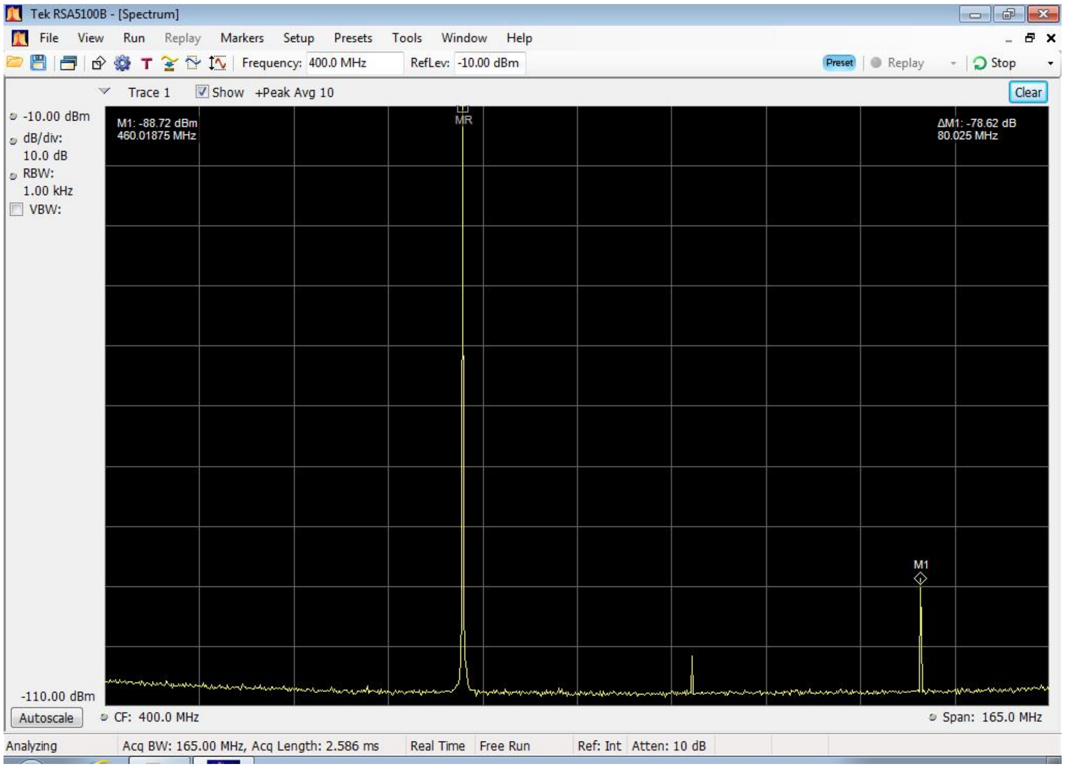

Figure 3. Performance of Option B16x showing IF/ADC-generated harmonic distortion at -78.62 dBc, after 10 averages to reduce noise variations on the signal.

Figure 3 is the same conditions as in Figure 2, except with 10 rms averages of the traces. The result is a less noisy measurement of about -79 dBc at M1.

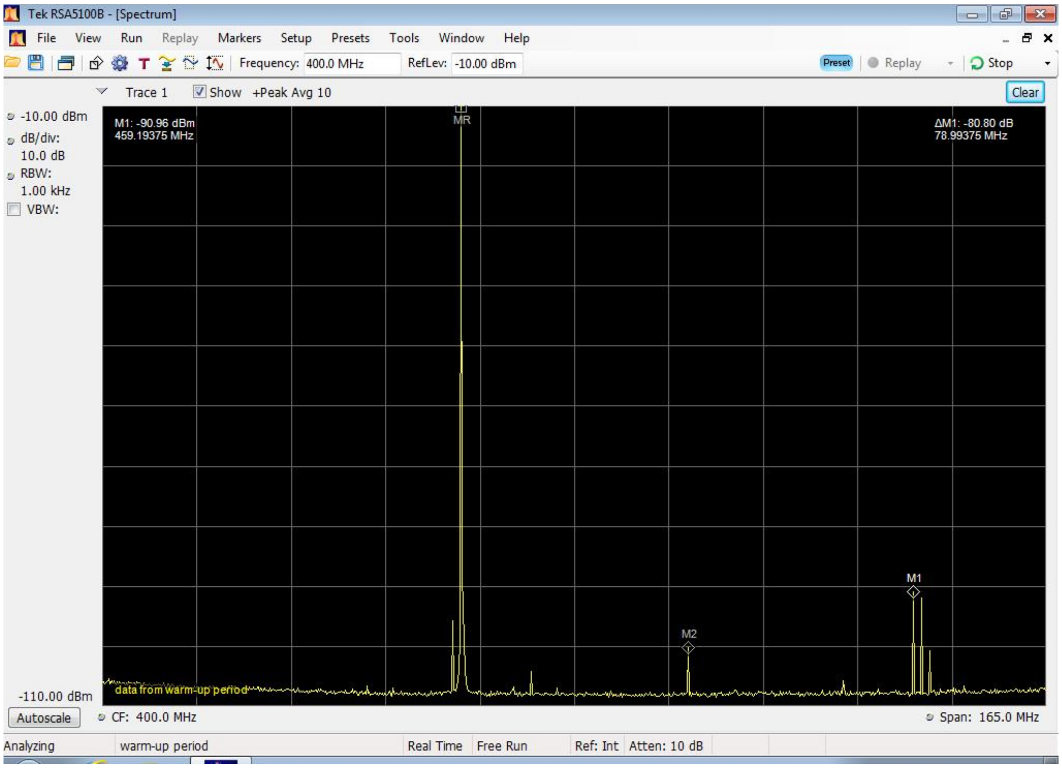

Figure 4. Tuning the input signal slightly causes the HD2 and HD3 products to separate in frequency, seen at M1.

Moving the signal even a few hundred kHz to 380.3MHz away splits these signals into their two respective harmonic distortion terms. HD3 is shown at marker M1 at -81 dBc. HD2 is the smaller term just to the right of M1. M2 is the other smaller spur in the system. These signals limit the SFDR to -73 dBc typical. Moving the input signal across the band produces spurs that move 1:1, 2:1, 3:1 and 4:1 across the band until they fall off the end of the screen. Increasing the frequency further will bring these terms in band at roughly these same levels as it aliases back into the band and moves in the opposite direction across the displayed span.

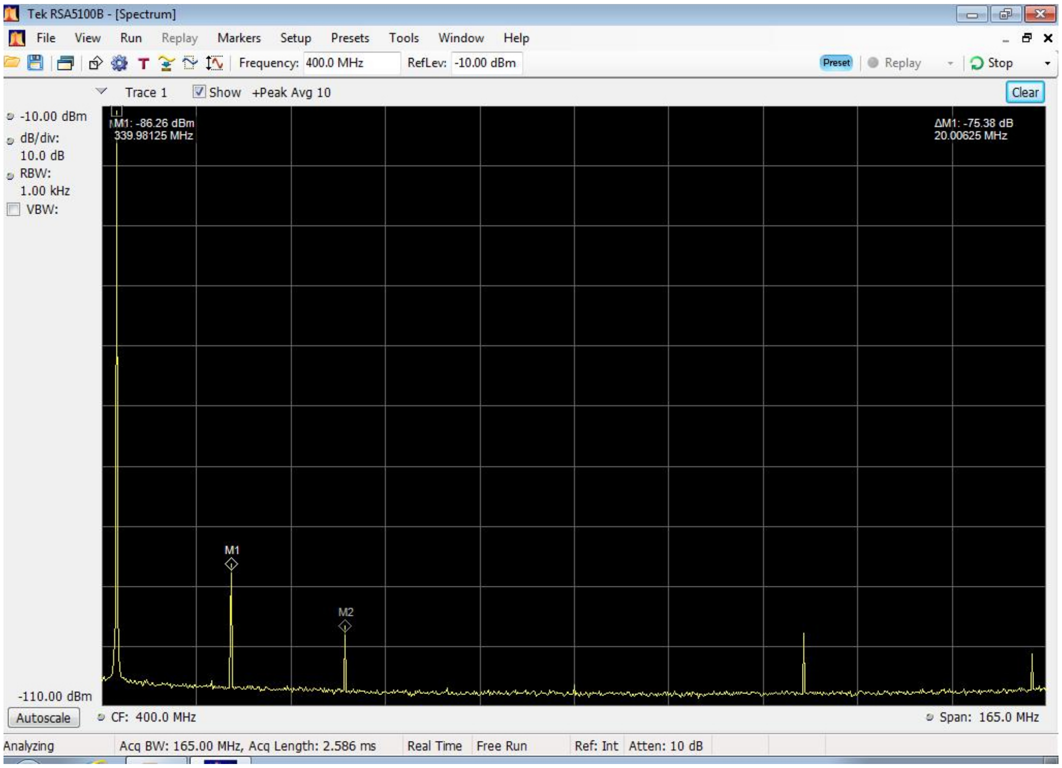

Figure 5. When the input signal is at the low end of the acquisition bandwidth (320 MHz), the IF/ADC harmonics are at M1 and M2. The second harmonic is dominant at about -75 dBc, with the third harmonic at -86 dBc.

For signals at the low side of the screen, a 320MHz signal produces the signals seen in Figure 5. M1 is HD2 at about -75 dBc in the IF, M2 is HD3 at about -86 dBc.

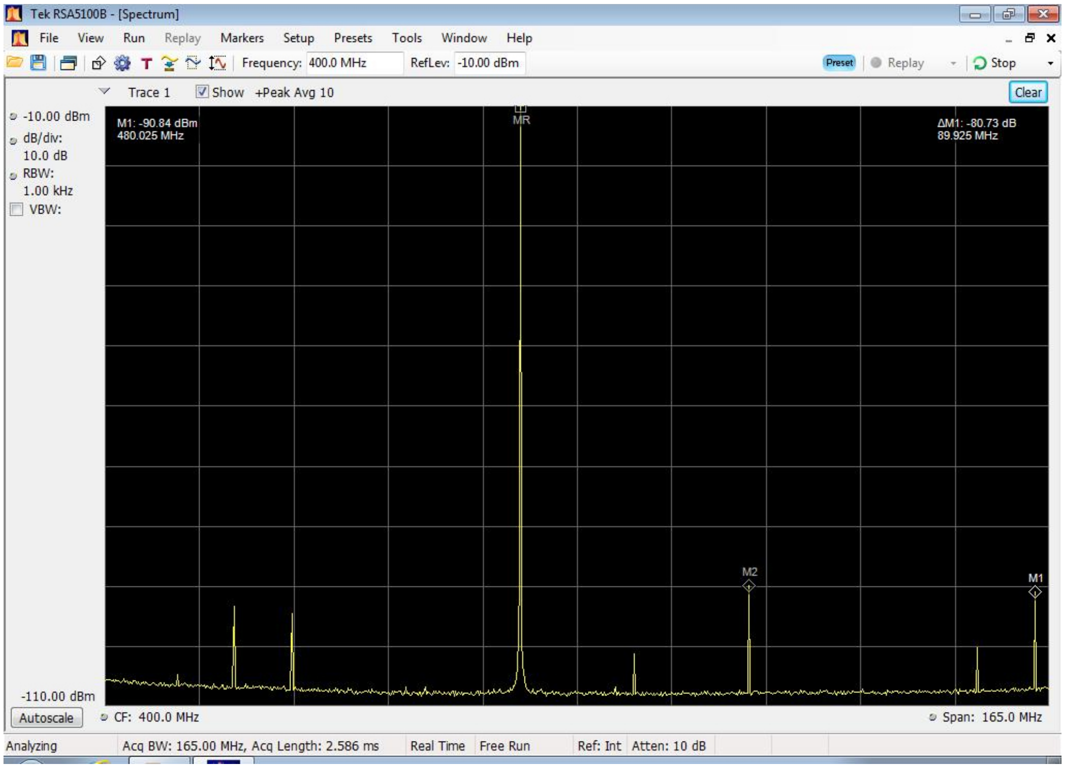

Figure 6. An example of when the third harmonic has 'folded' back into the analysis bandwidth. Here, a signal slightly lower than the center frequency of 400 MHz creates IF/ADC 2nd harmonic at M1 and the 3rd harmonic at M2.

With the input signal near the center of the screen at 390MHz (CF=400MHz) we see HD2 in the IF at M1 near the right hand side of the screen at -81 dBc and HD3 on M2 at about -80 dBc (Figure 6).

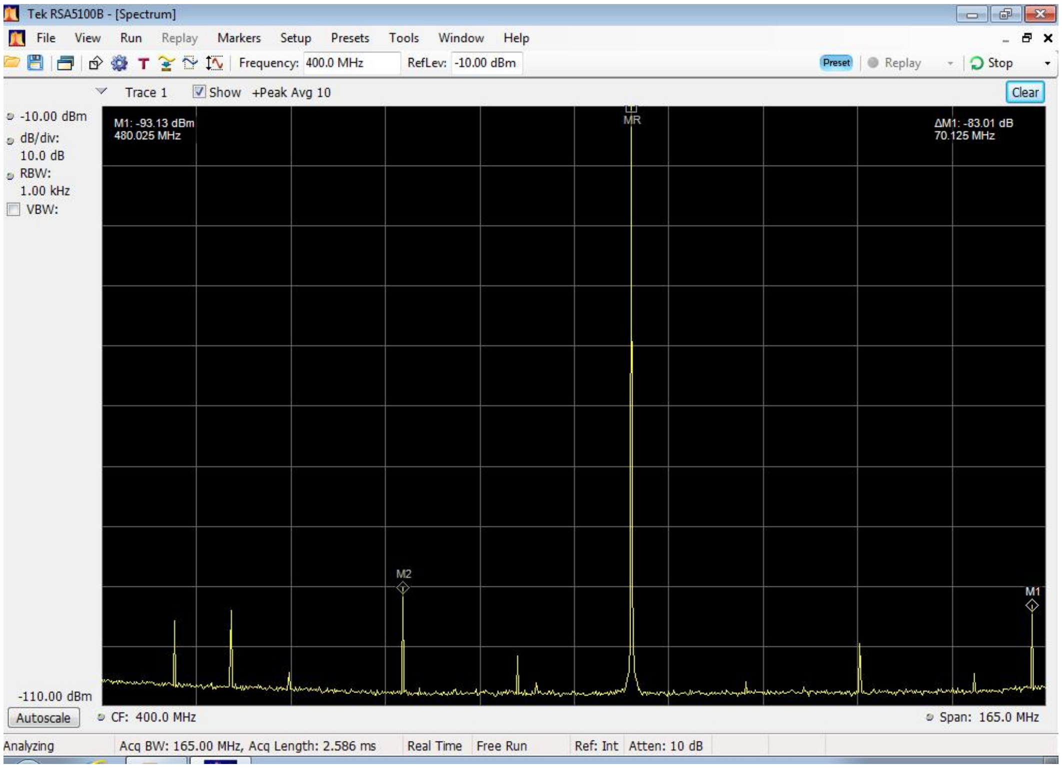

Figure 7. With the input signal slightly higher than the center frequency, the second harmonic appears at M1, and the third harmonic has now moved below the input frequency at M2.

As the input frequency increases to 410MHz we see HD2 at M1 of -83 dBc and other spurs M2 for HD3 at -80 dBc.

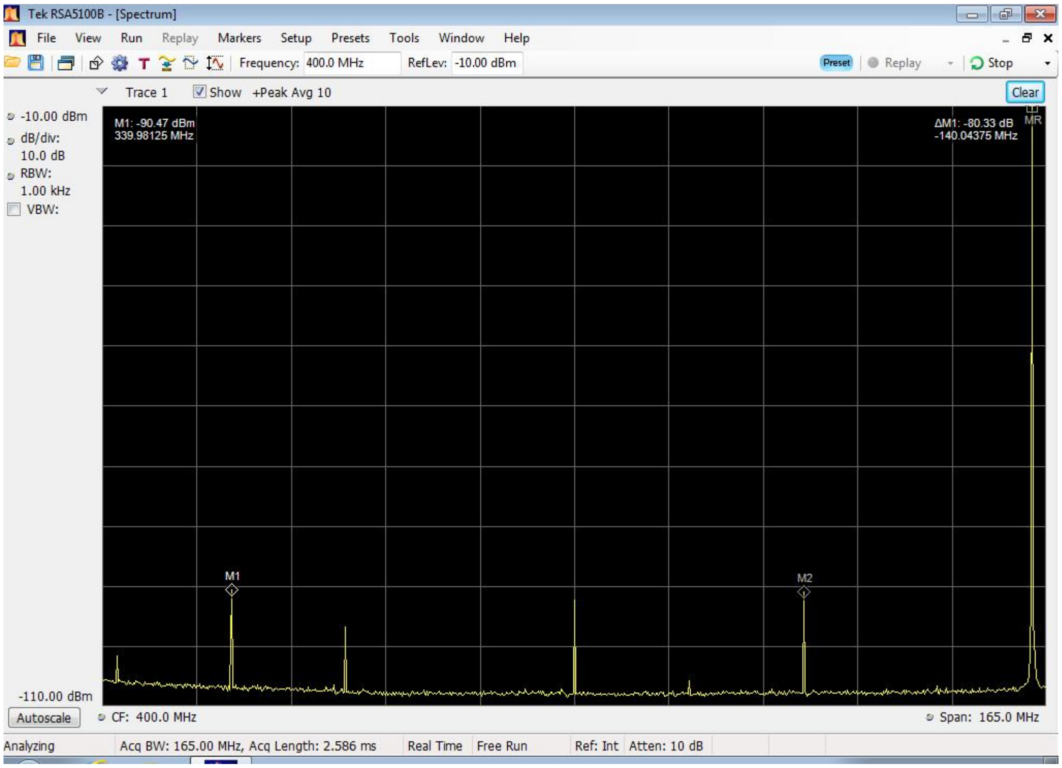

Figure 8. Moving the input signal to the upper edge of the acquisition bandwidth moves the 2nd harmonic to below the input frequency, and the 3rd harmonic to between the input and the second harmonic. The second and third harmonics travel in different directions and at different rates, making them difficult to identify on screen.

For signals at the right hand side of the screen at 480MHz we see HD2 at M1 of -80 dBc and other spurs HD3 at M2 at -81 dBc.

These spurs are relatively stable with a small amount of noise if averaging is used.

The performance of option B16x is similar to that of other real time spectrum analyzers available today. All available products use similar 14 bit digitizers applied to an intermediate frequency. While the exact input frequency required to see the harmonic distortion may vary, the levels of harmonics in the IF is very similar for all instruments.

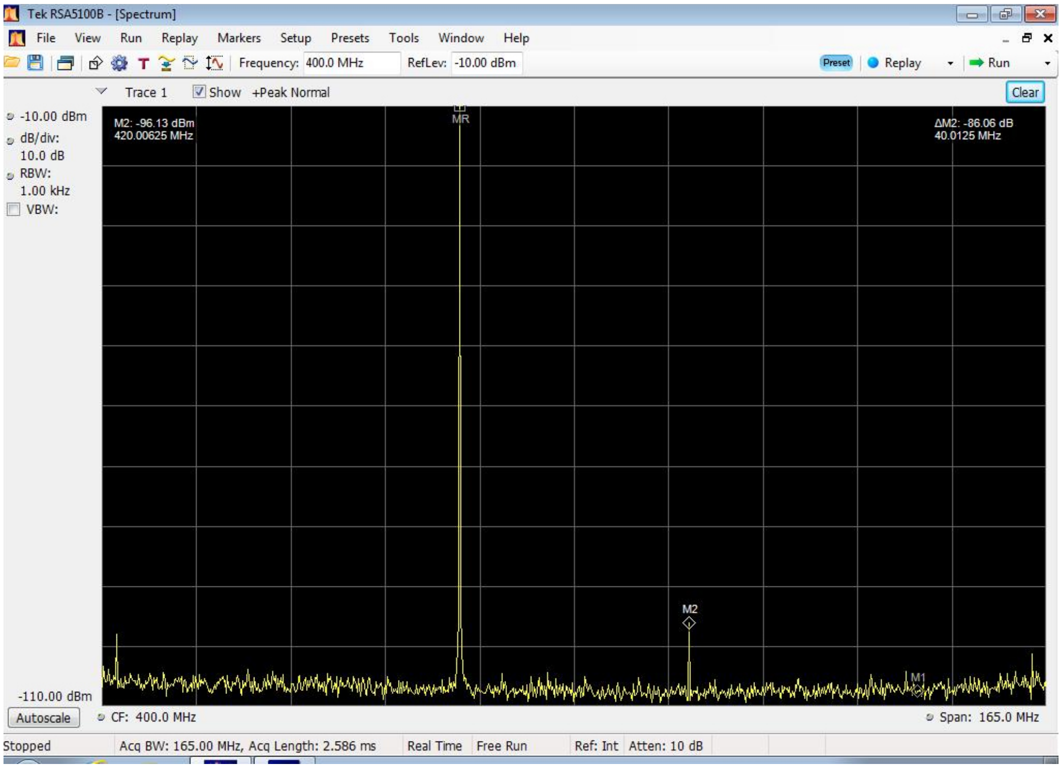

Figure 9. Option B16xHD, high dynamic range option, shows a 10 dB improvement over the standard acquisition system for IF/ADC harmonic distortion. Here, the 2nd and 3rd harmonics are at the same frequency at M1, but are nearly in the noise level. The new dominant spur, shown at M2 at -86.06 dBc is caused by the interleaving distortion of the two 16-bit digitizers used in the high dynamic range option.

B16xHD Option

Option B16xHD improves the SFDR to -80 dBc typical, a significant improvement over -73 dBc typical for the B16x option. The nature of the limiting components for this option have changed though. This design uses an improved digitizer with very low HD2 and HD3 which can be seen on the right hand side of the screen as indicated at M1 in Figure 9. This is comprised also of the two HD2 and HD3 terms on top of each other. The dominant spur is shown on marker M2 which in this screen shot is -86 dBc. This image term moves up or down with no averaging. This screen shot illustrates a case where this spur is higher than normal but it is still at -86 dBc. The system used is an interleaved ADC that produces interleave images that show up equidistant about the center of the screen at 1:1 and on the opposite side as shown at M2 for a single tone input. If the input is brought in on the left side of the screen, the spur will appear on the opposite side equidistant from the center of the screen to the input. As the signal moves toward the center of the screen, the spur on the right side moves toward the center of the screen. They cross over at the center and continue to move toward the edges of the screen. The spurious frequency is quite easy to predict so if they fall on a suspected DUT signal one can move the CF a bit and determine if the components are from the DUT or from the instrument. The majority of the time this option provides better than -80dB of SFDR. Due to the nature of the vector cancellation in the correction process and the noise on top of those signals, the peaks of this spur can range up to an 8 to10dB peak to peak value. There may be times that the peaks can reach to -78 dBc, but this is statistically likely to occur only at a 3 Sigma probability. This term is temperature sensitive so a fresh alignment should be done prior to a very sensitive measurement. The instrument will align itself for this spur for smaller temperature variations than the B16x option which is very stable but has worse SFDR.

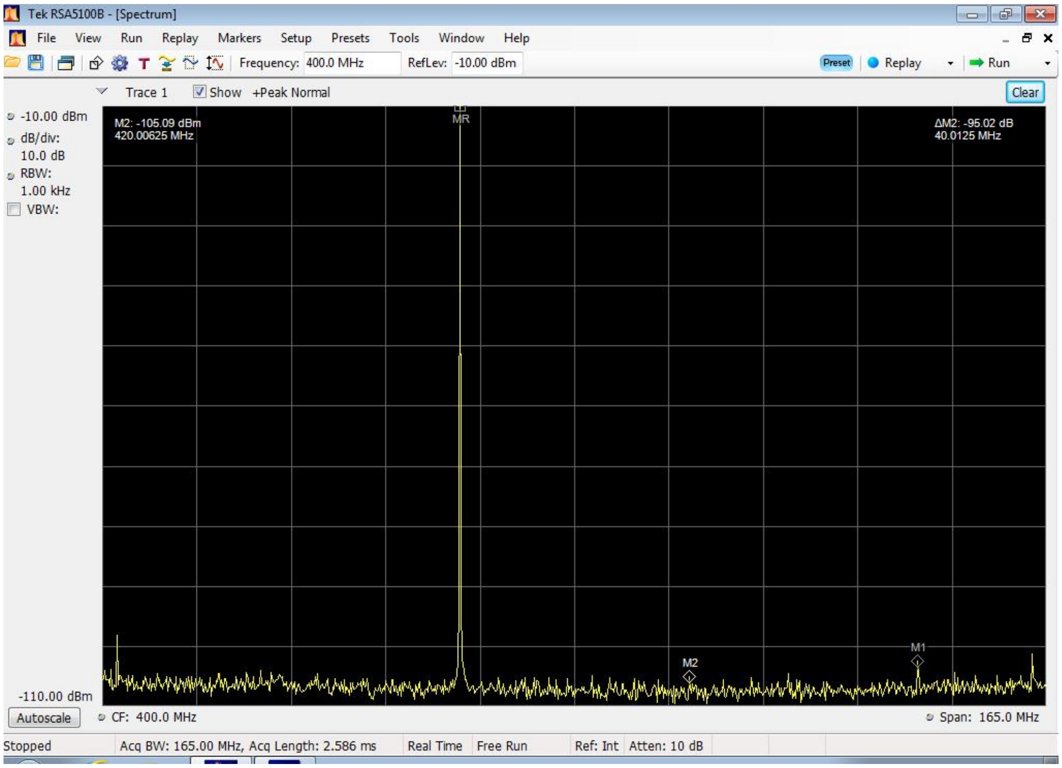

Figure 10. Option 16xHD showing the where the image spurious at M2 is nearly in the noise. This signal varies with time and temperature, but is lower than -80 dBc in nearly all cases.

Figure 10 illustrates a case with no averages where the M2 spur is very close to the noise floor. HD2 and HD3 are nearly non-existent. This case catches a very low M2 spur. In normal operation with no averages this signal will vary in a noise-like way between mid -80 dBc to -90 dBc. The signal on the far left edge of the screen is a non-dominant system spur that is well below the -80 dBc specification.

Figures 11-16 show the performance of the high dynamic range options as the carrier frequency is tuned throughout the input signal range of the instrument. The test conditions are similar to those shown when using the standard dynamic range options, but the resultant harmonic levels and spurious are substantially improved. See the caption headings for test conditions and results.

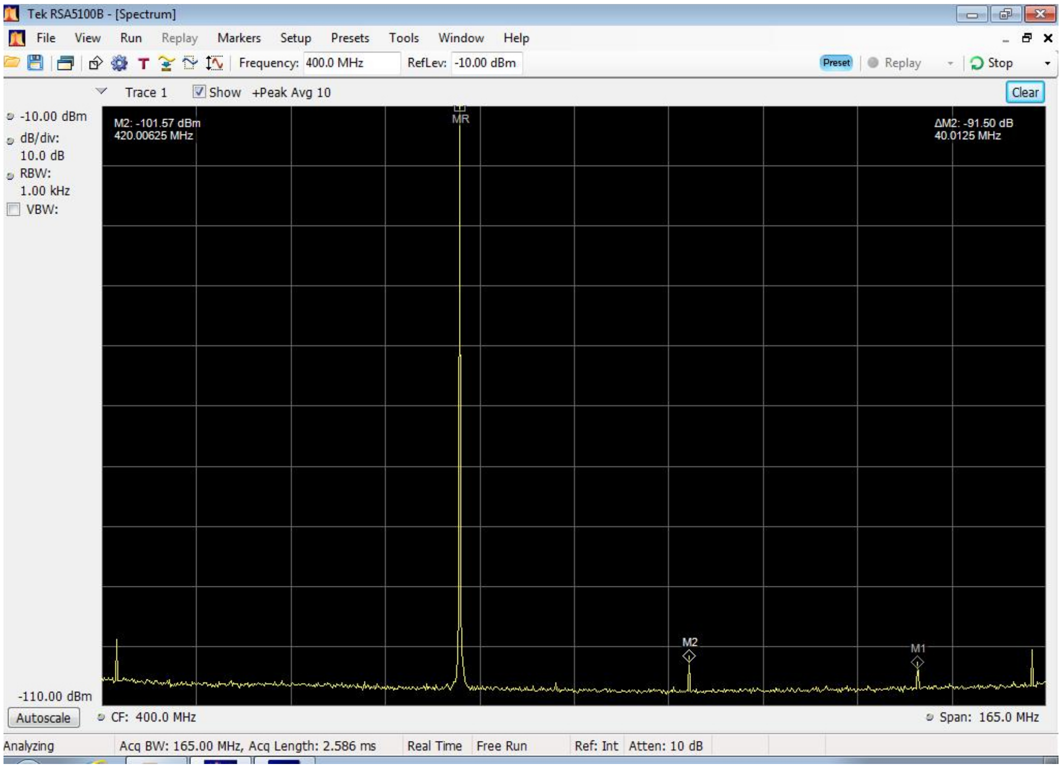

Figure 11. The image spurious after 10 averages, now at -91.5 dBc.

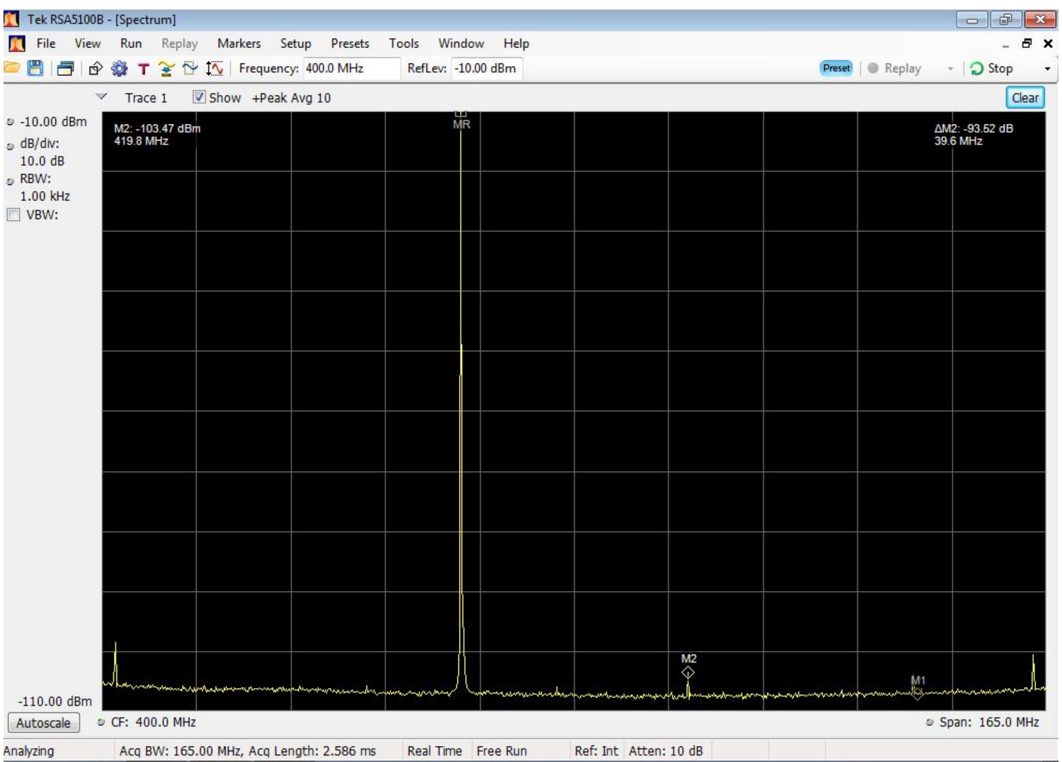

Figure 12. With an input of 380.3MHz where the HD2 and HD3 would be at M1, but are nearly non-existent due to the high dynamic range of Option B16xHD. M2 indicates the 1:1 image spur symmetrical about the center of the screen and lower than -90 dBc.

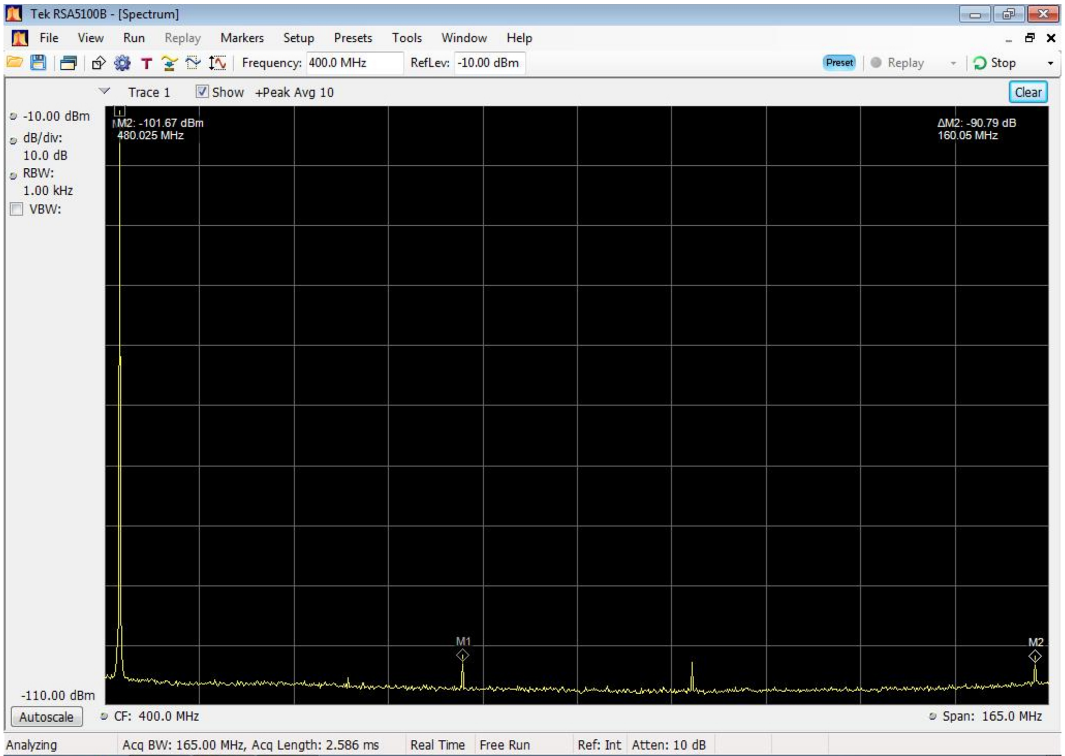

Figure 13. Option 16xHD with an input of 380.3MHz where the HD2 and HD3 would be split at M1 but they are still nearly non-existent. M2 indicates the 1:1 image spur symmetrical about the center of the screen and lower than -90 dBc.

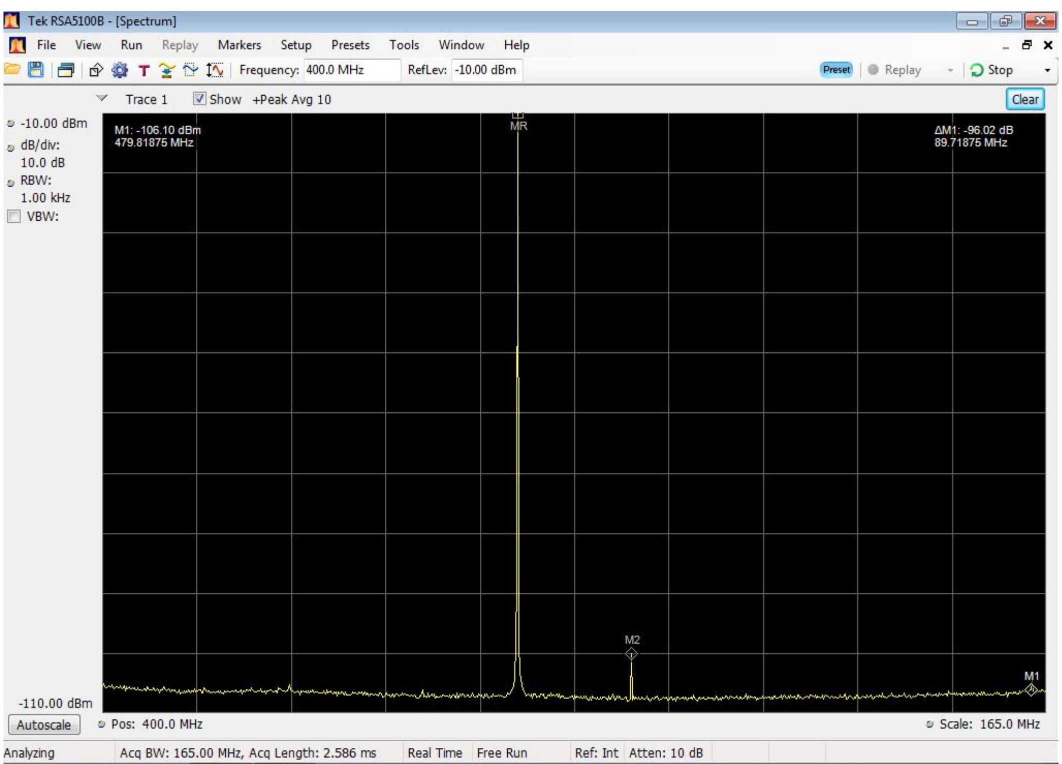

Figure 14. With an input at 390MHz, M1 is the HD2 that is in the noise and M2 indicates the 1:1 image spur at -96 dBc.

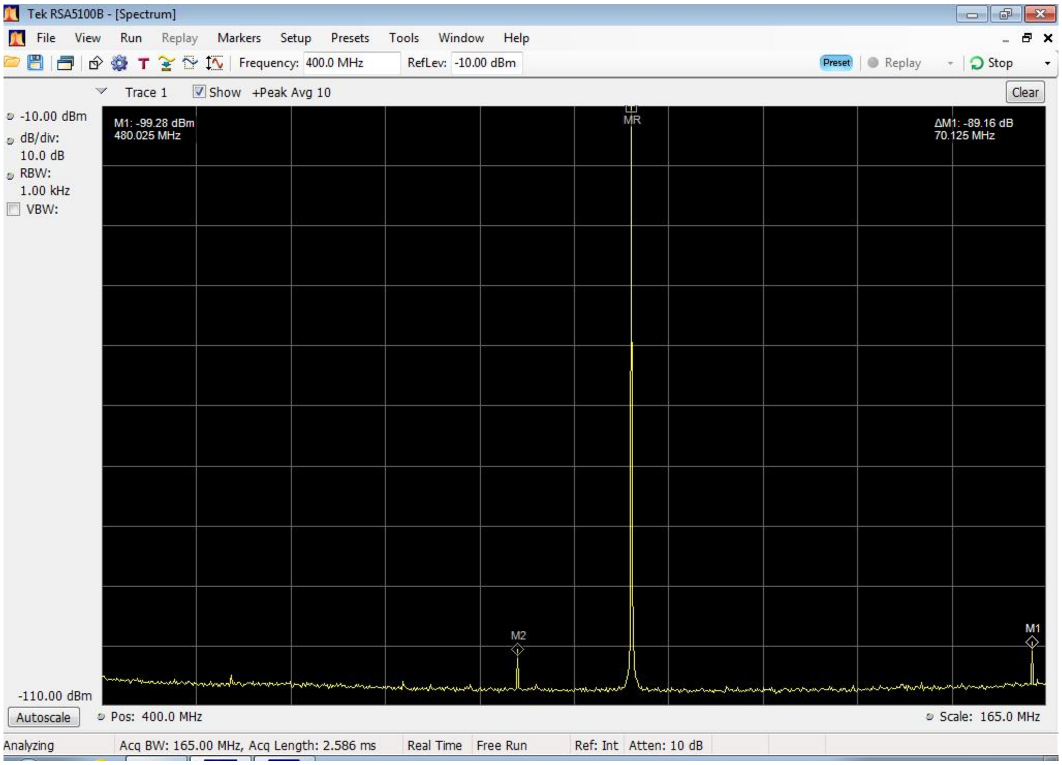

Figure 15. The input is at 410MHz. M1 is HD2 at -89 dBc and M2 is the 1:1 image at -90 dBc.

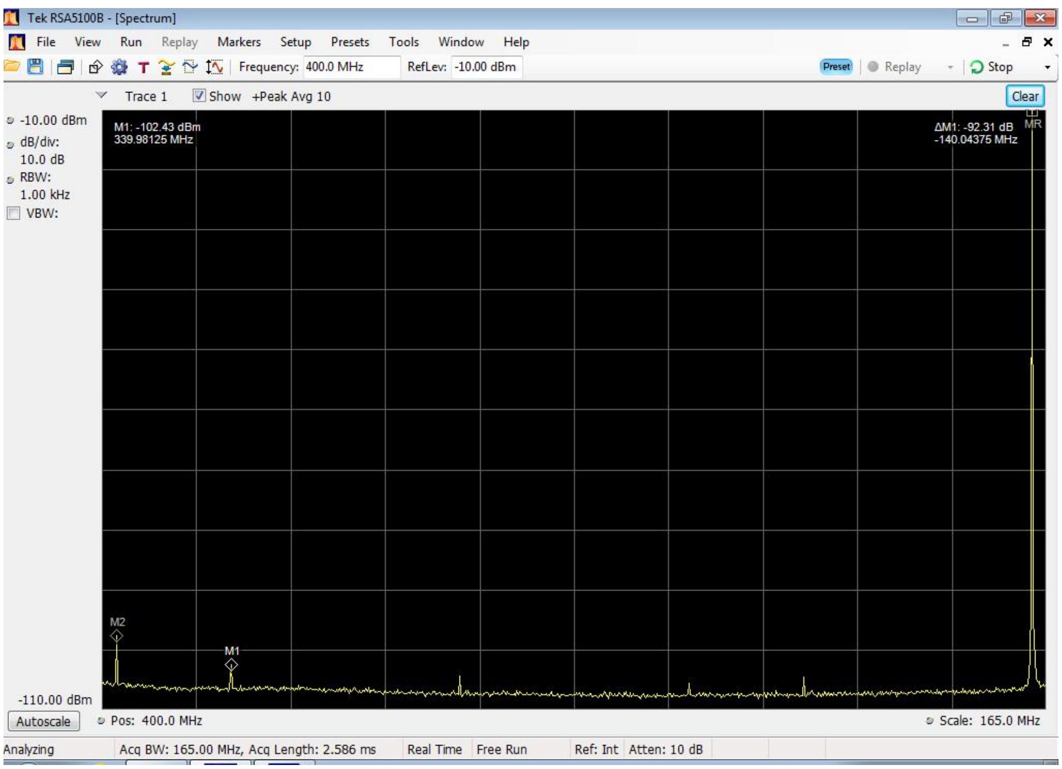

Figure 16. HD2 at -92 dBc (M1), with the 1:1 image at -87 dBc (M2)

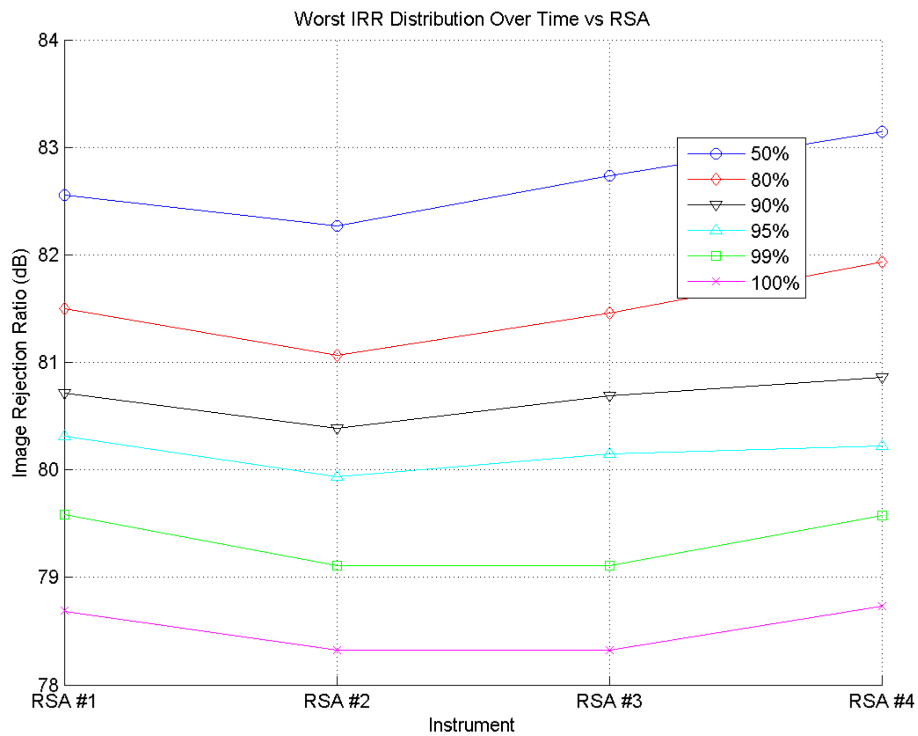

Figure 17. Probability of image level measured for 4 instruments. The 95% probability is at approximately -80 dBc, with a mean (50%) level of -82 to -83 dBc.

Other information about this B16xHD option

The image is temperature sensitive. To counteract this, the B16xHD option uses a thermally-stabilized element that maintains temperature within 2 degrees C over nearly the entire operating range of the instrument. In the case of large (> 5 degrees C) ambient temperature changes, the instrument may require alignment to optimize performance of the ADC system. This limited alignment takes only a few seconds, and can be turned off if operating conditions require no interruptions. If this is not desirable, a better choice might be the B16x option that has stable but worse spurs if the application doesn't demand the better SFDR of the B16xHD option.

The image level also varies with noise that occurs during the normalization and normal operation. The variation is consistent with statistics where a greater than 3 Sigma variation may be had very occasionally. During our performance evaluation testing on multiple units, we measured the spurious signals for each 500 kHz step across the 165 MHz acquisition bandwidth, a total of 330 measurements per test. The results of this testing were that 99% of the time, the worst case capture over many sweeps will remain below -79 dBc. 95% of time, the worst case capture will be under -80 dBc on our units. At the mean or 50% of the time the worst case will be below -82 dBc. Under most conditions you will not see a worst case unless you are at the exact frequency and time that a >3 sigma variation may happen. The Typical-Mean will be between -80 dBc and -90 dBc except for >3 sigma points of the noise. Figure 19 shows the image rejection probability of four of the instruments tested during our performance evaluation.

A video of the performance differences between the two options is available at www.tek.com/dynamicrange.

Preselection and RF/IF Images

This paper has focused on the distortion and spurious products present in the IF/AD system of wideband analyzers, including digitizer-related images. An important contributor to overall performance is the suppression of images that result in the RF and IF downconversion process. Tektronix real time spectrum analyzers are always preselected to avoid images. Most spectrum analyzers use narrowband tunable band pass filters, often YIG tuned filters (YTF) to serve as a preselector. These filters provide image rejection and improve spurious performance in swept applications by limiting the number of signals present at the first mixing stage. YTF's are narrow band devices by nature and are usually limited to bandwidths less than 50 MHz. These analyzers bypass the input filter when performing wideband analysis, leaving them susceptible to image responses when operating in modes where wideband analysis is required such as for real time signal analysis.

Unlike spectrum analyzers with YTF's, Tektronix Real Time Signal Analyzers use a wideband image-free architecture guaranteeing that signals at frequencies outside of the band to which the instrument is tuned don't create spurious or image responses. This image-free response is achieved with a series of input filters designed such that all image responses are suppressed. The input filters are overlapped by greater than the widest acquisition bandwidth, ensuring that full-bandwidth acquisitions are always available. This series of filters serves the purpose of the preselector used by other spectrum analyzers, but has the benefit of always being on while still providing the image-free response in all instrument bandwidth settings and at all frequencies.

Conclusions

Choose B16x Option when:

1. -73 dBc typical meets your requirements
2. Expected temperature environments may vary quickly
3. It is necessary that spurious be relatively constant and stable, and the standard spurious performance meets your requirements.

Choose B16xHD when:

1. Operation in a normal lab temperature environment is expected
2. There is the need for another 10dB of SFDR for -80 dBc typical-mean spec
3. Some noise variation in SFDR in the worst case is acceptable but most of the time below -80 dBc.

Appendix: Definitions of Specification Types

Specifications vary widely from manufacturer to manufacture. Tektronix supplies several categories of published performance for spectrum analyzers, outlined below. The specifications discussed in this article are P-Typ, or published typical performance.

Nominal: Characteristics that are described in terms of nominal performance—guaranteed, but without tolerance limits. Examples are number of trigger inputs, or physical dimensions and weight.

Specified Characteristics: Characteristics described in terms of specified performance with guaranteed tolerance limits, such as reference frequency accuracy and frequency response. Specified characteristics always include a description containing tolerance limits. Specifications are warranted to the customer, and are tested either directly or indirectly in manufacturing or by type-testing of instruments prior to manufacturing. Specifications that are checked directly are included in the Performance Verification document for the instrument.

Typical Characteristics: Characteristics described in terms of typical, but not guaranteed, performance. The values given are not warranted, but 80% of measured values will meet the specification with 80% confidence, unless otherwise noted, between 18C and 28C ambient, immediately after performing a full alignment. Typical characteristics are not tested in manual performance checks.

Typical-95: These are specifications that are impractical to verify in the field as they are based on statistical performance data across a large sample of instruments. Examples of this are Adjacent Channel Leakage Ratio (ACLR) dynamic range, and Absolute Amplitude Accuracy at all Center Frequencies.

A specification classified as (P-TYP-S95) denotes that the specification will be met on any particular instrument with 95% confidence. 95th percentile values indicate the breadth of the population ($\approx 2\sigma$) of performance tolerances are expected to be met in 95% of the cases with a 95% confidence, for any ambient temperature in the range of 18 to 28°C, immediately after performing an alignment. In addition to the statistical observations of a sample of instruments, these values include the effects of the uncertainties of external calibration references and aging over the course of the published calibration interval. These values are not warranted. These values are updated occasionally if a significant change in the statistically observed behavior of production instruments is observed.

Contact Tektronix:

ASEAN / Australia (65) 6356 3900
Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3759 7627
Canada 1 (800) 833-9200
Central East Europe and the Baltics +41 52 675 3777
Central Europe & Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
Germany* 00800 2255 4835
Hong Kong 400-820-5835
Ireland* 00800 2255 4835
India +91-80-30792600
Italy* 00800 2255 4835
Japan 0120-441-046
Luxembourg +41 52 675 3777
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Mongolia 400-820-5835
Mexico, Central/South America & Caribbean 52 (55) 56 04 50 90
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People's Republic of China 400-820-5835
Poland +41 52 675 3777
Portugal 80 08 12370
Puerto Rico 1 (800) 833-9200
Republic of Korea +822-6917-5000
Russia +7 495 664 75 64
Singapore +65 6356-3900
South Africa +27 11 206 8360
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Sweden* 00800 2255 4835
Switzerland* 00800 2255 4835
Taiwan 886-2-2656-6688
United Kingdom* 00800 2255 4835
USA 1 (800) 833-9200

* **If the European phone number above is not accessible, please call +41 52 675 3777**

Contact List Updated June 2013

For Further Information
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